IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

DECLARATION

I, Angus Forsyth MA (Cantab.), MPhil, PGDip, DipTrans (IoL), translator to Messrs. Falcon Translations Ltd of Capital Tower, 91 Waterloo Road, London SE1 8RT, England, do solemnly and sincerely declare as follows:

1. That I am well acquainted with the English and German languages;

2. That the following is a true translation made by me into the English language of the attached German documents;

3. That all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true;
    and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardise the validity of the application or any patent issued thereon.

Signed, this seventh day of June 2006,

London SE1 8RT, England

High frequency filter

The invention relates to a high frequency filter of coaxial
construction, in particular in the manner of a high frequency
switch (such as, for example, a duplex switch) or a band-pass
filter or band-stop filter.

In radio technological systems, in particular in the field of
mobile communications, a common antenna is often used for
transmission and reception signals. The transmission and
reception signals use respectively different frequency ranges,
and the antenna must be suitable for transmitting and
receiving in both frequency ranges. A suitable frequency
filtering means, with which, on the one hand, the transmission
signals are forwarded from the transmitter to the antenna and,
on the other hand, the reception signals are forwarded from
the antenna to the receiver, is therefore required for
separating the transmission and reception signals. High
frequency filters of coaxial construction are nowadays used,
among other means, for splitting up the transmission and
reception signals.

A pair of high frequency filters, which both allow through a
specific frequency band (band-pass filter), may, for example,
be used. Alternatively, a pair of high frequency filters,
which both block a specific frequency band (band-stop filter),
may be used. In addition, a pair of high frequency filters may
be used, of which one filter allows through frequencies below
a frequency between the transmission and reception bands and
blocks frequencies above this frequency (low-pass filter), and
the other filter blocks frequencies below a frequency between
the transmission and reception bands and allows through
frequencies   thereabove   (high-pass   filter).   Further

combinations of the aforementioned types of filter are also conceivable.

High frequency filters are often constructed from coaxial resonators, as these consist of milled and cast parts, as a result of which they are easy to produce. Furthermore, these resonators ensure high electrical quality and a relatively high degree of temperature stability.

Document EP 1 169 747 B1 describes an example of a generic coaxial high frequency filter. This filter comprises a resonator with a cylindrical internal conductor and a cylindrical external conductor, a capacitance, which influences the resonance frequency, being formed between a free end of the internal conductor and a cover fastened to the external conductor. The resonator further comprises a tuning element made from a dielectric material and with which the resonance frequency of the filter may be adjusted. The tuning element is movable in the internal conductor of the resonator, as a result of which the capacitance between the free end of the internal conductor and the cover of the resonator is altered and the resonance frequency is thus varied.

The publication "Theory and Design of Microwave Filters", Ian Hunter, IEE Electromagnetic Waves Series 48, Section 5.8, discloses coaxial resonator filters with a large number of individual resonators which are coupled to one another.

In the high frequency filters known from the prior art, it has been found to be disadvantageous that filters having low resonance frequencies lead to a large overall volume, and this in turn increases the material and machining costs. The large overall volume results from the fact that a low resonance frequency is achieved by a long internal conductor. Although

the resonance frequency may also be reduced by reducing the distance from the filter cover to the free end of the internal conductor, this has the undesirable effect that the dielectric strength of the resonator is reduced. If the distances between the free end of the internal conductor and the cover are too small, the voltage applied at this location soon results in breakdowns via the layer of air between the cover and the free end of the internal conductor, and this affects the transmission of signals and may destroy the filter.

The object of the present invention is, therefore, to provide a high frequency filter of coaxial construction which has both high dielectric strength and a low overall volume.

This object is achieved by the independent claims. Developments of the invention are defined in the dependent claims.

The high frequency filter according to the invention comprises an electrically conductive internal conductor configured as an internal conductive tube, an electrically conductive external conductor and an electrically conductive base which electrically interconnects the internal conductor and the external conductor. Also provided is a cover covering the high frequency filter with respect to the base. The cover has an inner side and outer side, the inner side pointing toward a free end of the internal conductive tube. In the high frequency filter, a dielectric layer having a relative dielectric constant greater than 2 is arranged between the outer side of the cover and the free end of the internal conductive tube. The radial extent of the dielectric layer substantially covers the cross section of the internal conductive tube at the free end thereof. As a result of a dielectric layer of this type, an increase in capacitance, and

therefore a reduction of the resonance frequency, is achieved, owing to the high dielectric constant, without increasing the overall volume. Moreover, as the dielectric layer substantially covers the entire cross section of the internal

5 conductive tube, the dielectric strength between the internal conductive tube and cover is improved.

In a particularly preferred embodiment, a high dielectric material having a relative dielectric constant greater than or

10 equal to 5, preferably greater than or equal to 8, particularly preferably greater than or equal to 9, is used as the dielectric layer. Materials having a much higher dielectric constant, for example materials having a relative dielectric constant greater than or equal to 40, may also be

15 used. For example, the constant may be between 40 and 80 or between 60 and 80. As materials having a high dielectric constant, ceramic materials, for example, in particular aluminum oxide ceramic, are used for the dielectric layer.

20 Preferably, the surface area of the radial extent of the dielectric layer is at least twice the surface area of the cross section of the internal conductive tube at the free end thereof. This provides extensive coverage of the internal conductive tube with dielectric material, thus ensuring a very

25 high dielectric strength.

In a further embodiment, the cross section of the internal conductive tube is substantially circular at the free end thereof. The radial extent of the dielectric layer may also be

30 substantially circular. If both the cross section of the internal conductive tube at the free end thereof and the radial extent of the dielectric layer are circular, the diameter of the radial extent is, in a preferred variation of the invention, at least as great as the diameter of the cross

section. Preferably, the diameter of the radial extent is at
least 1.5 times the diameter of the cross section. Moreover,
the external conductor may also have a substantially circular
cross section, the diameter of which is preferably at least
5   twice the diameter of the radial extent of the dielectric
layer.

In a particularly preferred variation of the invention, the
dielectric layer is arranged on the cover of the high
10 frequency filter, in particular is fastened to the cover. The
dielectric layer may, for example, be inserted in a recess in
the inner side of the cover.

The dielectric layer may be held in the recess by an
15 interlocking fit, in particular by an edge, projecting beyond
the edge of the dielectric layer, on the inner side of the
cover. Alternatively or additionally to the interlocking fit,
the dielectric layer may be held on the inner side of the
cover by an adhesion means, in particular adhesive. In a
20 further variation of the invention, the dielectric layer is
closed by the inner side of the cover.

In a further embodiment, the high frequency filter comprises a
plurality of resonators, a single continuous, at least
25 partially strip-like dielectric layer being provided for all
of the resonators.

The high frequency filter according to the invention is
preferably configured in such a way that as a result of the
30 configuration and coupling of the resonators, a duplex switch
is formed. A configuration as a band-pass filter or band-stop
filter is, however, also conceivable.

Embodiments of the invention will be described hereinafter with reference to the accompanying drawings, in which:

Fig. 1 is a side view of an embodiment of a resonator used in
5   the high frequency filter according to the invention;

Fig. 2 is a plan view of the resonator of Fig. 1;

Fig. 3 is a plan view of a modification of the resonator of
10 Fig. 2;

Fig. 4 is a plan view of the inner side of the resonator cover according to an embodiment of the invention;

15 Fig. 5 is a plan view of a band-pass filter in which a plurality of resonators as illustrated in Fig. 3 is used; and

Fig. 6 is a sectional view along the line I-I of the band-pass filter of Fig. 5.
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Fig. 1 is the side view of a resonator for use in a high frequency filter according to the invention. It is a resonator of coaxial construction extending along the axis A. The resonator comprises an electrically conductive cylindrical
25 internal conductive tube 1, the lower end 1b of which is inserted in a base 3. The base 3 is also cylindrical in its configuration and connected at its outer edge to a cylindrical external conductive tube 2. An electrically conductive connection between the external conductive tube 2 and internal
30 conductive tube 1 is produced via the base 3. A cover 5, having the inner side 5a and the outer side 5b, is located on the external conductive tube. A dielectric 6 (shown in black) is inserted in a recess on the inner side 5a. The dielectric opposes a free end 1a of the internal conductive tube 1. The

distance 4 between the cover 5 and the free end 1a of the internal conductive tube 1 is conventionally from 3 to 4 mm and may be reduced to as little as 0.5 mm. In Fig. 1, the dielectric layer is closed by the inner side of the cover. It

5 is also possible for the dielectric layer to protrude from the inner side of the cover or the inner side of the cover to project beyond the dielectric layer.

In the resonator of Fig. 1, a voltage superelevation is
10 produced in the event of resonance at the free end 1a, the amount of the voltage being proportional to the power of the signal acting on the resonator. The upper side of the free end of the internal conductive tube 1 and the inner side 5a of the cover form a plate capacitor, the capacitance C_{roof} of which is
15 directly proportional to the relative dielectric constant ε_r of the material between the capacitor. In the resonator of Fig. 1, high dielectric material 6 having a relative dielectric constant ε_r which is significantly greater than that of air is used. Preferably, the relative dielectric constant has values
20 of greater than 40. This means that the capacitance C_{roof} – in contrast to conventional resonators – is very high. The capacitance C_{roof} is a parallel capacitance to that of the actual resonator and is related to the resonance frequency of the resonator as follows:
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$$f = 1/2\pi\sqrt{L \cdot (C + C_{roof})}$$

f is the resonance frequency of the resonator, L the inductance of the resonator, C the capacitance of the
30 resonator and C_{roof} the described parallel capacitance to the upper side of the resonator.

The foregoing formula reveals that the higher C_{roof} is, the lower the resonance frequency. The dielectric 6 of the

resonator of Fig. 1 therefore provides a resonator having a low resonance frequency. According to the prior art, resonators having low resonance frequencies were achieved not by using a dielectric, but rather by reducing the distance between the cover and the free end of the internal conductive tube. However, limits are set for the reduction of this distance, as this greatly reduces the dielectric strength of the resonator. In order to avoid this problem, resonators according to the prior art use alternately wider internal conductive tubes, as a result of which the resonance frequency is also reduced. However, this leads to an increased resonator volume and therefore to higher material and machining costs. In contrast thereto, the resonator of Fig. 1 allows a low resonance frequency, a high dielectric strength and a low overall volume to be achieved.

Fig. 2 is a plan view of the resonator of Fig. 1. In this case, it is particularly apparent that the internal conductive tube 1 and the external conductive tube 2 are cylindrical in their configuration. The radial extent of the dielectric layer 6, the circular edge of which is denoted in Fig. 2 by 6′, is also obtained. In order to provide high dielectric strength even at small distances between the free end 1a of the internal conductive tube and the cover 5, the diameter d_1 of the dielectric layer is greater than the diameter d_2 of the cross section of the internal conductive tube. The diameter d_1 is preferably 1.5 times the diameter d_2. The diameter d_3 of the external conductive tube is substantially greater than the diameters d_1 and d_2. In a preferred variation, the diameter d_3 is twice as great as the diameter d_1.

Fig. 3 is a plan view of a modification of the resonator of Fig. 2. In the resonator of Fig. 3, the external conductor 2 is not cylindrical, but rather substantially square with

rounded corners. The shape of the internal conductor 1 and the
dielectric layer 6 is also cylindrical or circular. However,
it is also conceivable for the internal conductive tube or the
dielectric layer to have other shapes; in particular, they may

5   also be square in their configuration. Care must merely be
taken to ensure that the size of the radial extent of the
dielectric layer corresponds at least to the sectional surface
area of the internal conductive tube.

10   Fig. 4 is a plan view of a possible configuration of the inner
side 5a of the cover 5 from Fig. 1. For the sake of clarity,
the inner side of the cover is shown hatched. It may be seen
that an inner edge 5' of the cover projects beyond the
dielectric layer 6. This ensures, by means of an interlocking

15   fit, that the dielectric layer is held in the recess in the
cover 5. However, a large number of other holding mechanisms
are also possible for holding the dielectric layer 6 in the
cover 5. For example, the dielectric layer 6 may be glued in
place in the recess.

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Fig. 5 is the plan view of a band-pass filter in which four of
the resonators of Fig. 3 are used, the cover of the resonators
not being shown. The external conductors of the individual
resonators are interconnected via apertures 7, thus forming an

25   overall encircling housing 2'. Coupling of the resonators is
achieved through the apertures, in order to generate the
desired response of the band-pass filter. The extent of the
coupling is determined by the distance between the resonators
and by the size of the aperture. In this case, the center

30   frequency of the band-pass filter is proportional to the
length of the internal conductive tube 1.

Fig. 6 is a sectional view of the band-pass filter as
illustrated in Fig. 5 along the line I-I, the cover of the

band-pass filter being attached to the upper side. It may be seen that a continuous cover 5″ rests on the upper side of the housing 2′. As in Fig. 1, a dielectric layer 6, as a result of which the dielectric strength and the overall size of the band-pass filter are reduced, is, again, provided opposing the free end 1a of the respective internal conductor 1. Alternatively, a single continuous dielectric layer, in the form of a strip, may be provided, the strip extending in the longitudinal direction of the housing 2′ and having a width such that each internal conductive tube is covered by the strip.